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Development of Traction Features in Sprint Spikes using SLS Nylon Sole Units

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Abstract

A novel method for incorporating traction features within sprint shoe sole units using selective laser sintering (SLS) was investigated. A bespoke test fixture for measuring traction between track surface and sole unit was developed and is described here. The traction properties of both commercially available and SLS sprint shoes were evaluated. With respect to the SLS sole units the evaluation focused upon whether or not they met the minimum traction requirements deemed necessary for sprinting. The potential to create a fully functional sprint shoe sole unit using additive manufacturing technologies is discussed.

Keywords: Spprining; Footwear; Traction; Sprint Spikes

1. Introduction

The ability to generate substantial propulsive forces is a critical factor in sprint performance. During the first few strides from the blocks, 100 m sprinters can develop a backward directed horizontal force component exceeding 120% of their body weight [1]. A slipping movement between the foot and ground is not desired as it reduces the horizontal ground reaction force and dissipates energy, in addition to increasing the risk of injury to the athlete. Traction features are therefore an integral component of sprint shoes. The authors believe that commercially available sprint shoes create sufficient traction with typical track surfaces, under normal conditions, to avoid slipping.

The only published research, known to the authors, to examine the interaction between sprint shoes and track surfaces determined that the spike plate of the sprint shoe, located at the forefoot, was observed to be in total contact

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with the track surface at the time of maximum horizontal force application [2]. There is a dearth of information in the literature with regards to the traction properties of commercially available sprint shoes and the forces they are able to cope with while remaining in a fixed position relative to the track surface. It is thought that there is much more to gain, in terms of insights to inform sole plate design, from a better understanding of the interaction between sprint shoes and track surfaces.

Traditionally, sprint shoes have utilized removable spikes (screw-threaded, tapered metal pins). Spikes vary in design but are essentially very similar in function. Modern sprint shoes provide traction via molded features incorporated into the sole plate of the shoe combined with typically 5-9 removable metal spikes. As such, the majority of commercially available sprint shoes are similar in design and construction with respect to traction features. The ability to design sprint shoe traction features that do not incorporate removable spikes provides greater design freedom, particularly if the traction features utilized are integral to the sole plate. Additive manufacturing allows the production of complex geometries in a single process, permitting the production of a sprint sole which incorporates traction features as a single unit. Previously, selective laser sintering (SLS) of nylon has been used to produce sole units with mechanical properties desirable to sprint shoe sole units with regards to longitudinal bending stiffness [3].

The suitability of using selective laser sintered nylon to create a sprint shoe sole unit which incorporates traction features is explored by investigating the relationship between the pin geometry, quantity, placement and track traction. The traction features on the SLS sole units were evaluated with respect to whether or not they met the minimum traction requirements deemed necessary for sprinting and their performance compared to that of the commercially available sprint shoes. The current paper discusses the evaluation of traction properties of both commercially available and SLS sprint shoe sole units.

2. Methods

2.1. SLS Sole Units

An additive manufacturing process, namely SLS, was used to produce sprint shoe sole units, incorporating traction features. Additive manufacturing methods are free-form additive processes that do not require tooling to produce parts. This elimination of tooling has several advantages including economic low-volume production and increased design freedom [4]. In the SLS process, a laser is used to selectively sinter layers of the powdered nylon-12 material. The machine is initially filled with powdered material and is pre-heated to a temperature slightly below the sintering temperature of the material. A laser then scans the cross-sectional area identified for the current slice, sintering the powder. A fresh layer of powder is deposited across the part bed and the process is repeated, during which time the previous layers of un-sintered powder act as a support for any overhanging features. This layering and sintering is repeated until the final 3-D geometry has been completed.

Two traction designs were selected for construction (see Fig. 1). The first sole unit (SLS A) utilizes traction features based on the needle and pin spike shape. The pins have a base diameter of 5 mm and a height of 4 mm. There are a total of 80 traction features per sole unit. The second design (SLS B) was based on the Christmas tree shaped spike. The traction features have a base diameter of 6 mm and a height of 4 mm. There are a total of 30 traction features per sole unit. Both sole units were assembled with a New Balance SDS 606 sprint shoe upper, UK size 9.

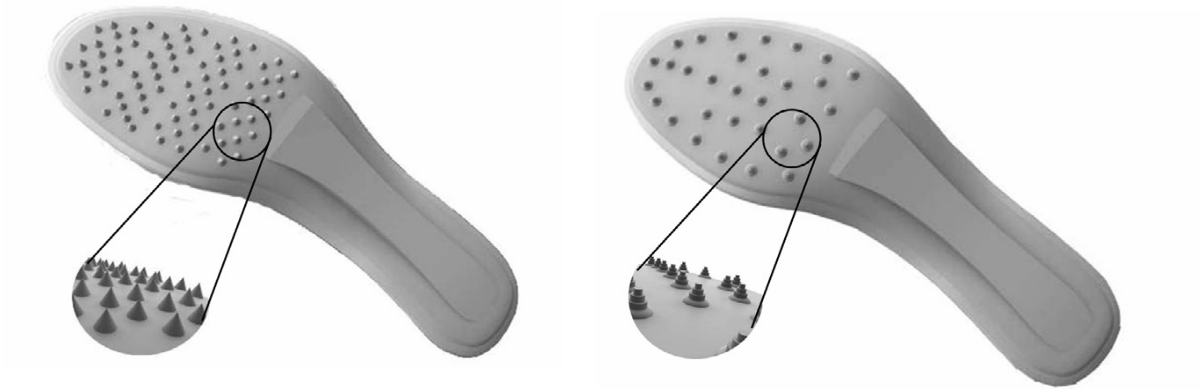

Fig. 1 (a) first (SLS A) and (b) second (SLS B) traction designs on the SLS sole units

2.2. Test Shoe Selection

The commercially available sprint shoes selected for testing were marketed towards 100m sprinters. The test shoes, UK size 9 (28 cm) are detailed in Table 1.

Table 1

BRAND	MODEL	REMOVABLE SPIKES
Mizuno	Tokyo	6 Cone Pins
Asics	Hyper-Sprint	7 Cone Pins

2.3. Test Fixture

The traction properties of both commercially available and SLS sprint shoes were evaluated using a purpose built test fixture (see Fig. 2). The test fixture was designed based on the ASTM standard for testing traction characteristics of the athletic shoe-sports surface interface (ASTM F 2333-04). The main features of the apparatus follow the guidelines of the ASTM standard. Some aspects were, however, modified. One modification is the manner in which the test shoe is secured to the apparatus. The standard test method ASTM F 2333-04 specifies that the test shoe be mounted on a foot form, creating a tight fit capable of properly transmitting forces through the shoe material to the outsole-playing surface interface. Alternatively, a mounting insole was specially constructed, using fused deposition modeling (FDM) technologies, to be tightly fit inside the test shoe. This insole mates with a complimentary clamp securing the shoe and insole, thereby allowing the application of a vertical force while holding the test shoe stationary.

The test fixture consisted of a low friction linear guide rail and carriage system (DryLin® Double Rail WS-16-60-300, L300mm and DryLin® Carriage W16-60-20, L200mm x W104mm, static load capacity Coy, Coz of 8400N). A sample of a typically used track surface (Polytan PUR) was mounted on the carriage, and fastened in a specially constructed plate using carpet tape, on which the test sprint shoe was placed. A normal load was applied to the shoe/track system using a screw thread arrangement, compressing the clamp down onto the shoe at the desired position, and measured using an in-shoe pressure measurement system (Tekscan® F-Scan Mobile system), located in the test shoe, underneath the mounting insole. Horizontal forces were produced coupling the frictionless sled and Instron testing machine (Instron 3365 Dual Column Testing machine, 5kN load capacity, 1000 mm/min maximum speed) housed in Loughborough University's Sports Technology Institute. A range of forces, both typical of and exceeding those encountered in sprinting were able to be applied to the track-shoe system.

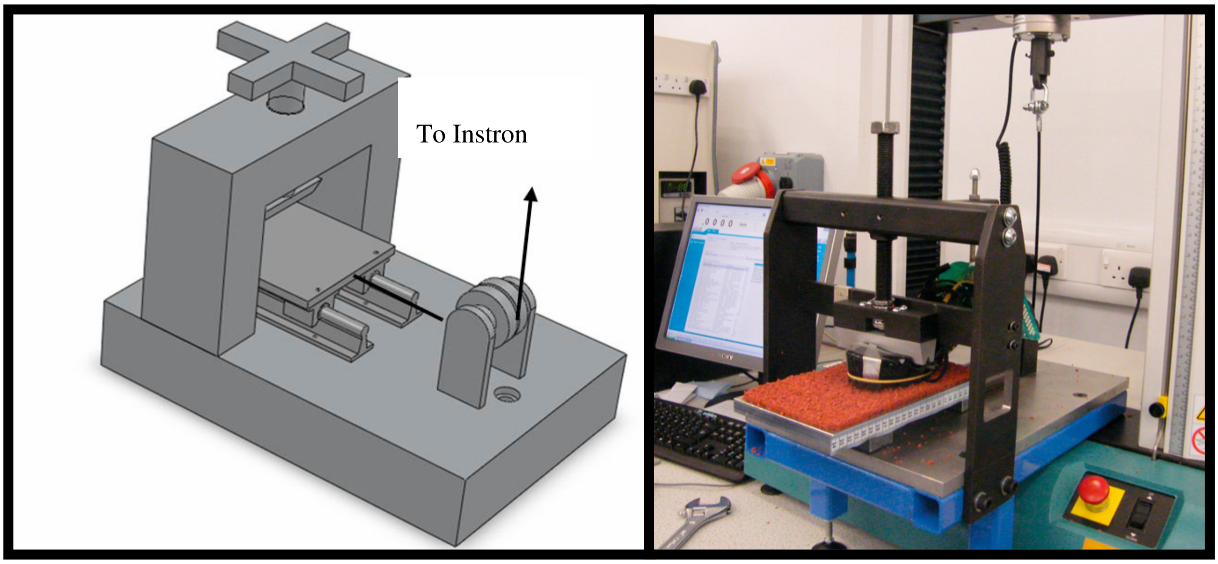

Fig. 2 (a) schematic and (b) actual traction rig.

2.4. Experimental Methods

Prior to testing, the base plate of the apparatus was secured to the base of the Inston machine to minimize unwanted movement of the apparatus throughout testing. The in-shoe pressure measurement insole (Tekscan® F-Scan Mobile system) and the mating insole were placed inside the test shoe. The shoe was then placed on the track surface, mounted on the apparatus, and mated with the clamp to achieve the desired insole test position. All trials were completed with the clamp in the middle position of the insole, allowing for the normal load to be distributed beneath the forefoot of the test shoe. The desired vertical force was then applied to the sprint shoe using the screw thread arrangement. The shoes were tested at normal loads of 500, 1000, 2000 and 3000N, replicating the vertical forces achieved typically by male sprinters [5,6].

Once the shoe was in position and the desired vertical loading applied, the mounted track surface was pulled by the Instron machine for a distance of 100mm at a rate of 1000 $mm \cdot min^{-1}$. The horizontal force achieved by the sprint shoe-track surface interaction and the extension of the Instron were recorded at 100Hz. Four trials at each of the levels of vertical loading were performed. Initially, one trial at each of the normal loads of 500, 1000, 2000, and 3000N was performed and the interaction between the shoe and track surface recorded using the high speed video (Photron Fastcam SA1.1). Any sprint shoes that showed heavy wear or failure of the traction features during these initial trials was excluded from further testing. Subsequently, the remaining three trials at each normal load level for each of the test shoes were performed in random order. The track surface was replaced when visible wear was apparent.

3. Results

After the initial test trials were completed, the SLS B sprint shoe was excluded from further testing as there was visible fracture of several of the traction features. The results for the remaining three sprint shoes are presented as a mean of the four trials. The graphical data in Fig. 3 shows the horizontal force recorded through displacement of the sprint shoes a distance of 100 mm at the various levels of normal loading.

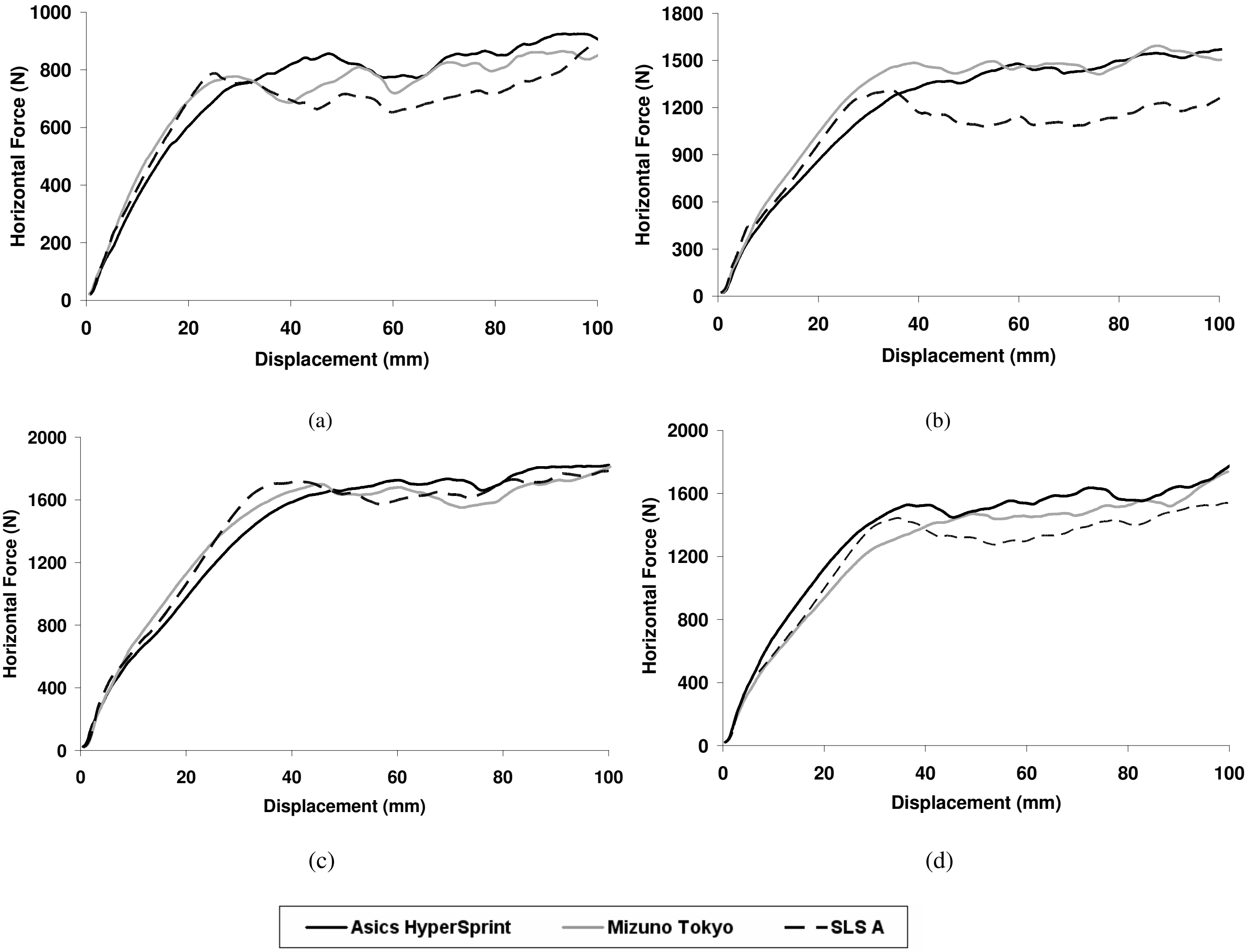

Fig. 3 Horizontal force versus extension at normal loads of (a) 500N (b) 1000N (c) 2000N and (d) 3000N for the Asics HyperSprint, Mizuno Tokyo and SLS A sprint shoes.

4. Discussion & Conclusions

The results demonstrate that SLS A sprint shoe is able to generate traction forces consistent with the commercially available sprint shoes tested, across the levels of normal loading examined. At lower levels of normal load, the key concern was slipping of the sprint shoe relative to the track surface. The results, however, did not give evidence that SLS A sprint shoe would be more likely to slip during a sprint run than the commercially available sprint shoes. At higher levels of normal load, heavy wear or failure of the traction features was the main concern. Although the SLS B sprint shoe showed failure of the traction features early in the testing, SLS A sprint shoe demonstrated minimal wear and no failure of any of the traction features. Hence, geometry of the traction features is an important factor in the constructing functional traction features able to withstand typical loading conditions encountered in sprinting without failing.

The current investigation has shown that the potential to create a fully functional sprint shoe sole unit using additive manufacturing technologies is indeed promising. Although a number of potential limitations in the testing method, such as the low sliding velocity and the static position of the shoe during testing, may undermine the applicability of these results to actual sprinting, the initial results indicate that SLS sprint shoe sole units incorporating traction features are able to cope with forces typically encountered in sprinting without slipping or failure of the traction features. Further investigations could focus on human performance testing to more fully evaluate the effectiveness of the traction features.

The SLS process offers several advantages over conventional manufacturing methods including the ability to produce complex geometries and cost effective, low-volume manufacture. These attributes lend themselves well to the production of personalized footwear. Combining the ability to vary the mechanical properties and the potential to create a fully functional sprint shoe sole unit using additive manufacturing technologies provides a means to more fully examining the effects of longitudinal bending stiffness in sprinting.

Acknowledgements

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